

New EN60204-1

overcurrent protection

of SELV-PELV lines in

control panels and

consequent new

requirements for AC/DC

power supplies

- the new EN60204 coming into force on 01-01-2010 introduces two changes :
- 1 - it takes on EN60950 std “*Electric Safety fire risk reduction*” also for SELV- PELV cable lines
- 2 - art. 11 is deleted and now emergency stops can be controlled by electronic devices
- as a consequence of point 1 it enforces to cut-off overcurrent on SELV-PELV lines to prevent fire risk
- as a consequence of point 1, 2 it takes on the EN61131-1 *Programmable Controllers, General Standards* and EN61131-2 *Equipment Requirements and Tests for the stability of the 24Vdc feeding the controls*

- EN61131 gives the limits for the rated voltage of the electronic controls such as PLC etc.
- as PLC must work for 10ms after 24Vdc drop to zero if 24Vdc drops under 21.6V longer than 10ms the PLC is no more feeded thus the system is out of control
- consequently, p. supplies must supply $\geq 21.6V$ for 10ms full load to bridge up the AC line when it drops to zero for 10ms (voltage sag)
- if 24Vdc drops under 21.6V longer than 10ms the PLC is no more feeded thus the system is out of control
- also to avoid failure on 24V lines to shut down the psu, it's required to prevent overcurrente on 24V by applying protections capable to cut off failures within times indicated here below :
- short circuit must be cutted-off within 10ms
- overload must be cutted-off within 5sec @ 1.5 of rated current of the protection

- new EN60204 is aware that 24Vdc is supplied by switching power supplies (par. 6.4.2)
- and is aware that switching psu have overcurrent protections to prevent internal failures caused by overload or short circuit on 24V lines, which overcurrent curve $U-I-t$ vary greatly from a psu to another
- some psu overload protection switch-off within few ms at +5...20% overload level
- some are capable to supply +50... +100% for few seconds or minutes jet with stable 24Vdc
- for the sure switch-off of overcurrent protections, thus for 24Vdc reliability, the different behaviour of overloaded psu must be carefully considered

- to assure continuous functions of the controls during a failure on 24V lines it's a must to :
- **cut-off a short circuit within 10ms, as PLC work for 10ms after 24V drop to zero**
- **cut-off overloads within 5s at a current not exceeding 1.5 x I_n of adopted protection**
- so, meanwhile the psu feed +50% overload current **it must supply $\geq 21.6V_{dc}$ as well**
- most of the DIN rail psu overload capacity ranges between +5...20%
- and when current values exceed +5...20% the output voltage drop to zero instantly
- and controls are no more supplied

Fuses and thermo- magnetic circuit breakers (mcb)

- fuses and mcb are devices capable to cut-off a current when it exceeds a certain value for a certain time (I-t characteristic curve)
- fuses and mcb works with current even if voltage is almost zero
- but PLC, sensors, actuators to work require also a stable 24Vdc ±10%
- as any voltage source cannot keep a stable output voltage during a short circuit
- consider that in case of short circuit the 24Vdc supplied by psu drops almost to zero until the overcurrent protection switch-off

A,B,C,D I/t switch-off curves

	A	B	C	D
T	$I_1 (t \geq 1h)^{1)}$	$1,13 \times I_n$	$1,13 \times I_n$	$1,13 \times I_n$
	$I_2 (t < 1h)^{2)}$	$1,45 \times I_n$	$1,45 \times I_n$	$1,45 \times I_n$
m	$I_4 (t \geq 0,1s)^{3)}$	$2 \times I_n$	$7 \times I_n$	$15 \times I_n$
	$I_5 (t < 0,1s)^{3)}$	$3 \times I_n$	$10 \times I_n$	$20 \times I_n$

T = sganciatore termico

m = sganciatore elettromagnetico

Note 1 : I / t curves of the thermal switch “T” are the same for all the four curves

Note 2 : current values are given for AC ; with DC voltage $I_4 - I_5$ current of “m” switch must be multiplied x 1.41

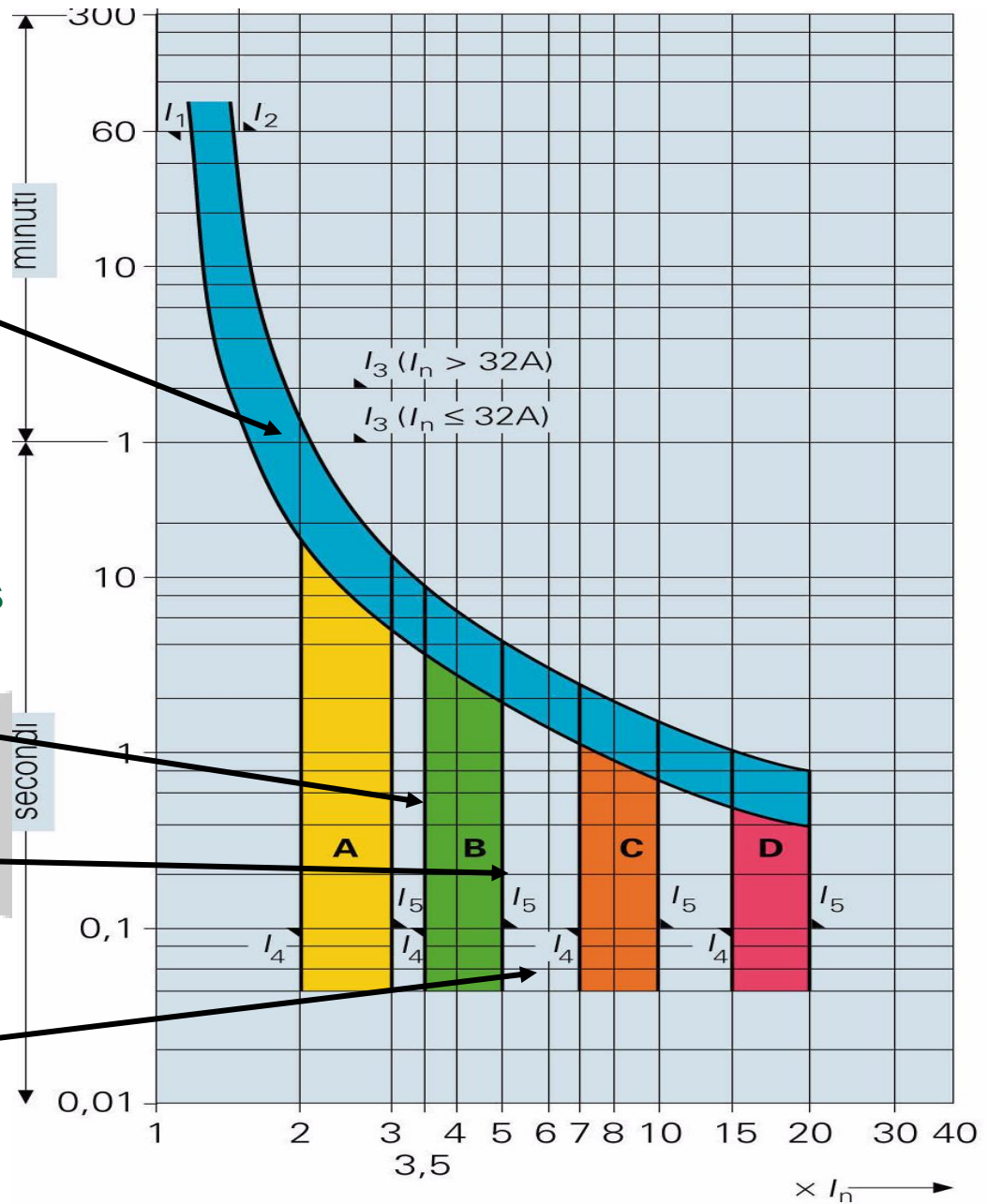
I/t curve of Thermal switch

A, B, C, D are the magnetic switch-off min-max current ranges

min switch-off current

max switch-off current

“Sure switch-off current” must always exceed max switch-off current



- **I/t curve: a certain current for a certain time**
- **the “sure swicth-off” of a mcb is reached only if **I/t** are higher than max switch-off values indicated by the curves**
- **the switch-off of thermo magnetic mcb has two modes**
- **A: “instantaneous” swicth-off <100ms occur only in case of short circuit, actuated by means of the electromagnetic “current relay”**
- **B: switch-off actuated by the thermal relay activated by current within 1.13...1.45 x In**
- **it takes always more than 5s the consequence of such long time is that the p.s output recovers to OVD protection and the 24Vdc drops to zero**

- Fuses as overcurrent protections
- fuses are inexpensive, efficient and accurate
- but the norm requires to assure that *“when a fuse blows it must be replaced with one having same ratings”*
- it’s quite a suggestion not to use fuses to protect lines having a fundamental function for safety
- none can be sure that the fuse will be replaced with the right value tested to guarantee the sure switch-off
- and also Europe and US have different standard curves and fuses types
- to use a on/off switch type overcurrent protection avoid this risk

- the max current that can flow through any circuits is limited by :
 1. overcurrent limit of the current-voltage source (the psu U-I-t limits)
 2. total R of the line = $R_{wires} + R_{connections} + R_{protection} + R_{residual\ of\ failed\ load} + other\ R$
- given the rated current of the psu, you must know its overload limit and peak short circuit current
- and also their durations as the switch-off of the overcurrent protections requires a certain current for a certain time

- the circuit to be protected includes :
 1. power supply (psu, with its U-I-t curve)
 2. overcurrent protection (with its I-t curve)
 3. wires, connections and other components which parasitic resistances are connected in series and summed
 4. and then the failing load, which R can have very different values depending on the kind of failure affecting it
- all these four parameters must be coordinated to each other to allow always the sure switch-off current to flow through the circuit in the “Worst Case”

- **definition of overload current of a psu:**
max overcurrent at which the psu jet gives $U_n - 10\%$ (21.6Vdc in case of 24Vdc)
- over max overload (ovd) limit, the output voltage drops almost to zero
- **definition of short circuit current of a psu:**
max current peak supplied by the psu applying to its output a load with R lower than R at which in the circuit flows the max overload current (see next slide)
- short circuit-ovd current capacity depends on engineering choices on components rating and on the technology adopted for U-I-t characteristic

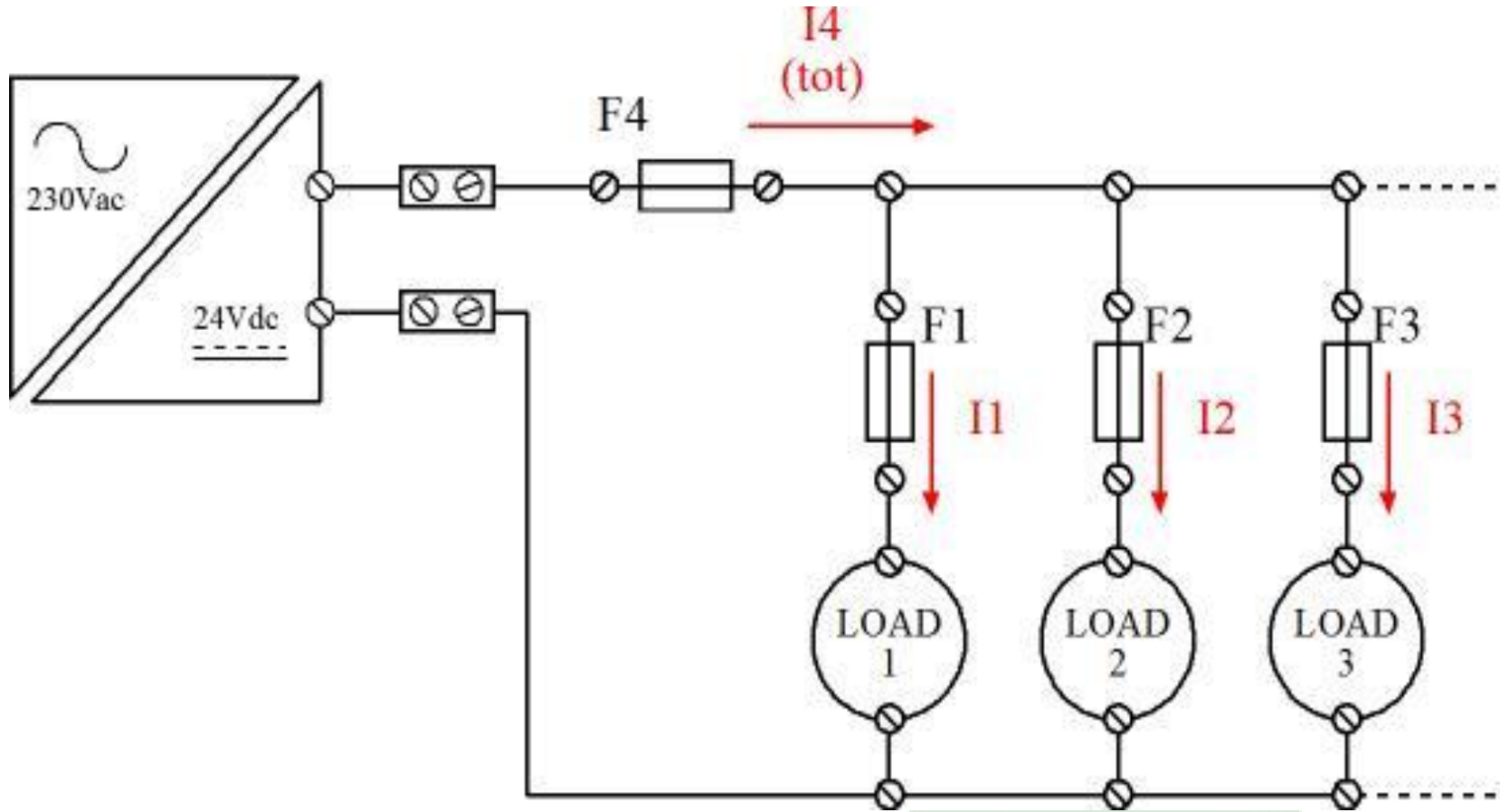
- for correct psu / protection matching consider first the short circuit / overload curve of the psu
- overload and short circuit “seen” form psu output
- for psu 20A-24V $R = 1.6 \Omega$ is a normal 15A load
- for psu 10A-24V $R = 1.6 \Omega$ is a +50% overload
- for psu 5A-24V $R = 1.6 \Omega$ is a “short circuit”
- for a 10A-24V psu the rated load is $R = 2.4 \Omega$
- if it allows +50% overload, R load limit is $R = 1.6 \Omega$
- so its output “see” a $R < 1.6 \Omega$ as a short circuit, its output go into protection and 24V drop to zero
- the boundary between load and overload is variable and depends on the rated current and on I-U-t curve of the psu adopted
- so a line overcurrent protection that works fine with a certain psu, wouldn't work at all with psu having same rated current but different U-I-t curve

- **matching psu and short circuit protection**
- **C10 sure switch-off = $I_n \times 10 \times 1.4 = >140A$**
- **B10 sure switch-off = $I_n \times 5 \times 1.4 = > 70A$**
- **none 10A psu give 70A or 140A peak current**
- **sure switch-off within 10ms requires to choose the rated current of the mcb lower than 50% of psu rated current**
- **eg. a B5 mcb with our 10A psu, in case of short circuit switches-off (always depending on line resistance)**
- **but we have still the problem of the switch off within 5s in overload conditions as you must consider that the most powerful psu have overload capacity limited to $1.5 \times I_n \times 5\text{sec}$**

- **matching psu and overload protection**
- **the most powerful psu have nevertheless an overcurrent capacity limited to $1.5 I_n \times 5\text{sec}$ or so**
- **the I-t switch off curves of mcb in overload conditions are equal for all mcb**
- **A10, B10, C10 with 15A switches off in ~60s**
- **A10, B10, C10 with 20A switches off in ~20s**
- **also with 10A psu capable of 20A for one day, to cut-off an overload within 5s with a B10 is not possible**
- **to cut off an overload within 5sec with A10,B10, C10 mcb it requires $\geq 60A \times 5\text{sec}$**
- **A5, B5, C5 mcb to switch-off within 5s require all a current of $I_n \times 6 = \geq 35A$ and only with 30A psu or higher might be ok**

- **the norm allow to insert overcurrent protections onto single loads / lines instead of a main protection with same I_n to the rated current of the psu**
- **this allow accurate matching of the current of each single protections with the rated current of each single loads / lines, lower compared to the rated current of the psu**
- **this solution has also the advantage to allow the selective switch-off of each protections which can cut-off only the failing load or line improving 24Vdc reliability and also facilitating to find out the failure**

SELV-PELV circuits and protections

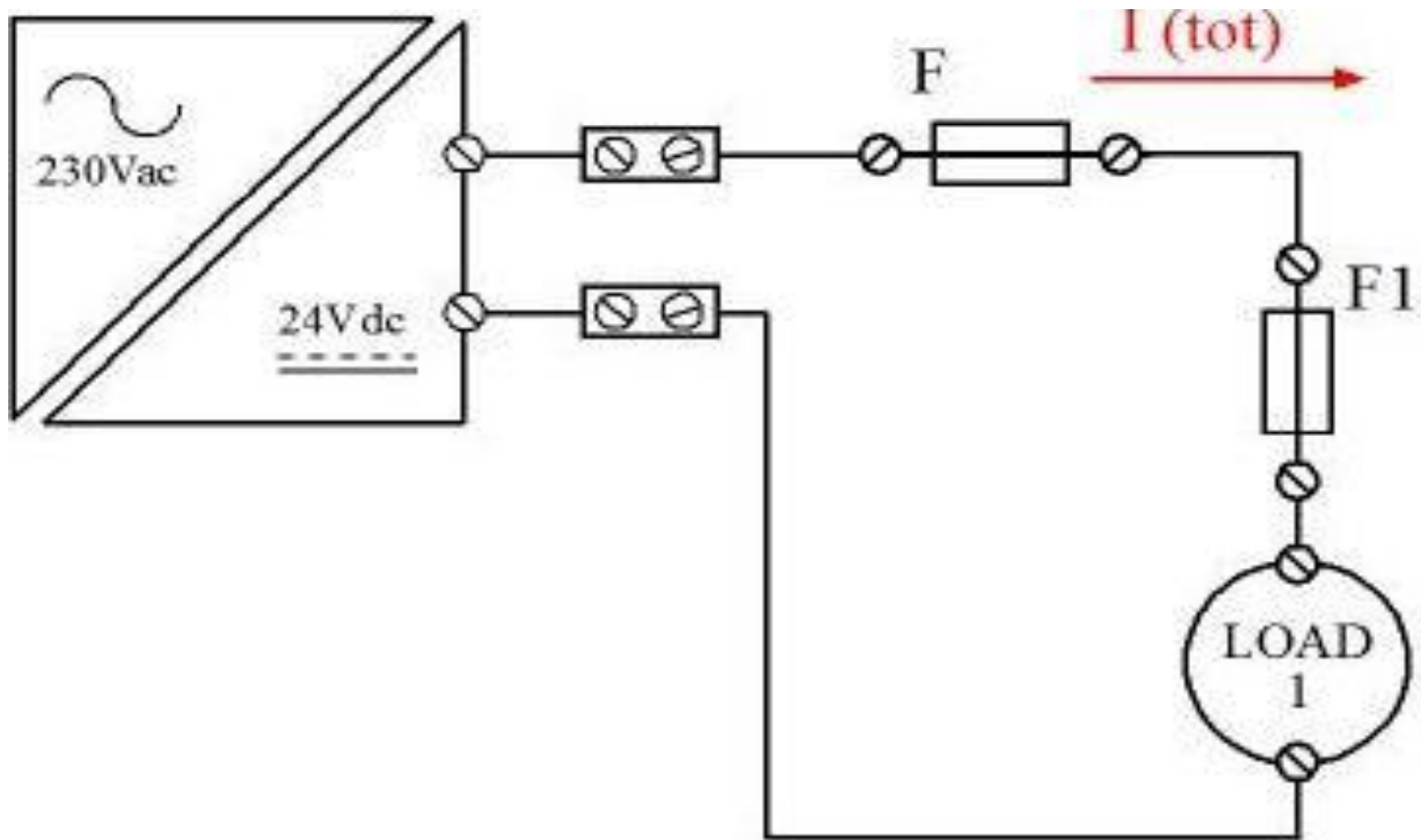


**F1, 2, 3 are protections matched with each single load current
F4 main protection has to be matched with total current so it
requires higher switch-off current than F1, F2, F3**

- matching the line protection to the psu must always consider the total line resistance
- a C2 mcb has a series resistance of $\sim 0.35\Omega$
- any short circuit have always a residual resistance which never can be assumed to be zero as often it exceeds few hundred $m\Omega$
- if failing load has for eg. 0.3Ω , the line might have a total resistance that do not allows the sure switch off of the mcb
- the only reliable method is to make practical sure switch-off tests in the worst conditions

the boundary between
“*sure switch-off current*”
and “*no switch-off current*”
is in the range of hundreds
mΩ of line resistance

Simple circuit and series resistances



a simple circuit with 10 connections might have a resistance that cannot be neglected

Total line resistance into details

- **R of a circuit with 10 connections, 1 psu, 2 feed through screw terminal blocks, 1 mcb, 1 load**
- **R of a 4mm² screw terminal block $R \cong 0.0005\Omega$**
- **R of a contact wire/ferrule $R \cong 0.003\Omega$**
- **R of a unipolar C2 mcb $R \cong 0.35\Omega$**
- **2 terminals, + 20 contacts wire/ferrule/t.block + mcb C2 = $R \cong 0.41 \Omega$**
- **if failed load has a residual $R \cong 0.3\Omega$**
- **even taking $R_{wires} = 0\Omega$, R_{total} is = 0.71Ω , which onto 24V allows $I = 33.8A$ thorough the line circuit**
- **in this case we have a current only a little higher than sure switch-off current within 100ms of a C2 mcb, which is $2A \times 10 \times 1.4 = 28A_{dc}$**
- **and a 2.5mm² stranded wire has $R = 0.007\Omega \times m$ @ 25°C ambient**

Resistance of feed thorough terminal blocks

- a 4mm² screw type terminal block has
 $R \cong 0.0005\Omega$
- a 4mm² spring type terminal block has
 $R \cong 0.0020\Omega$
- **the series resistance of a spring type terminal block is four times higher than on a screw type terminal block**
- in applications with many connections screw type terminal blocks help to get a lower total line resistance which help to get the sure switch-off of overcurrent protections

A new way to manage emergency stop



- the deletion of art.11 from the new edition of the EN60204 opens new ways for the engineers
- emergency stops can be **commanded**, transmitted, and actuated by electronic devices such as PLC, industrial PC, remote I/O, wireless and blue tooth devices ...
- of course it's required that those devices satisfy the suitable IEC-EN standards
- eg. for machinery with risk class higher than 2 it is now possible to use safety PLC also for the emergency stops

- **emergency stops changes**
- from a “passive” stop achieved by pushing a red pushbutton which cut-off the supply voltage of a circuit
- now it's possible to transmit - receive -actuate an emergency stop command though a chain of devices which to work must be supplied with 24Vdc
- **as a consequence the reliability of the 24Vdc feeding controls, commands and actuators now paly a fundamental part to assure machinery safety**
- **so the power supply feeding the 24Vdc plays an active part on the safety chain**

- for engineers who will use PLC, PC, I/O, wireless etc... for safety functions they asks that
- **“if an operator gives an emergency stop command, the emergency command must be safely transmitted and received to actuate a reliable emergency stop”**
- ***but this would be not possible if the failure that caused the operator to give the emergency stop command if a second, or contemporary, or consequent failure would cause the drop of the 24Vdc feeding controls and commands***

Cabur helps engineers to satisfy the new EN60204

- **cables protection, stability of the 24Vdc and power supplies**
- **the new psu Series CSF and CSG have overload capacity higher than +50% for 5sec**
- **our 20A, 30A and 40A 3phase models gives +50% and 24Vdc for 5s and the highest short circuit current peak**
- **all models are provided with alarm contact controlled by a voltage threshold circuit at $U_{out} < 21.6Vdc$ and red led for overload display**
- **the most compact dimensions jet with very low operating temperature at full load**
- **all models are UL508, UL60950, Gost, File Cb, approved**

Cabur Electronic Protection

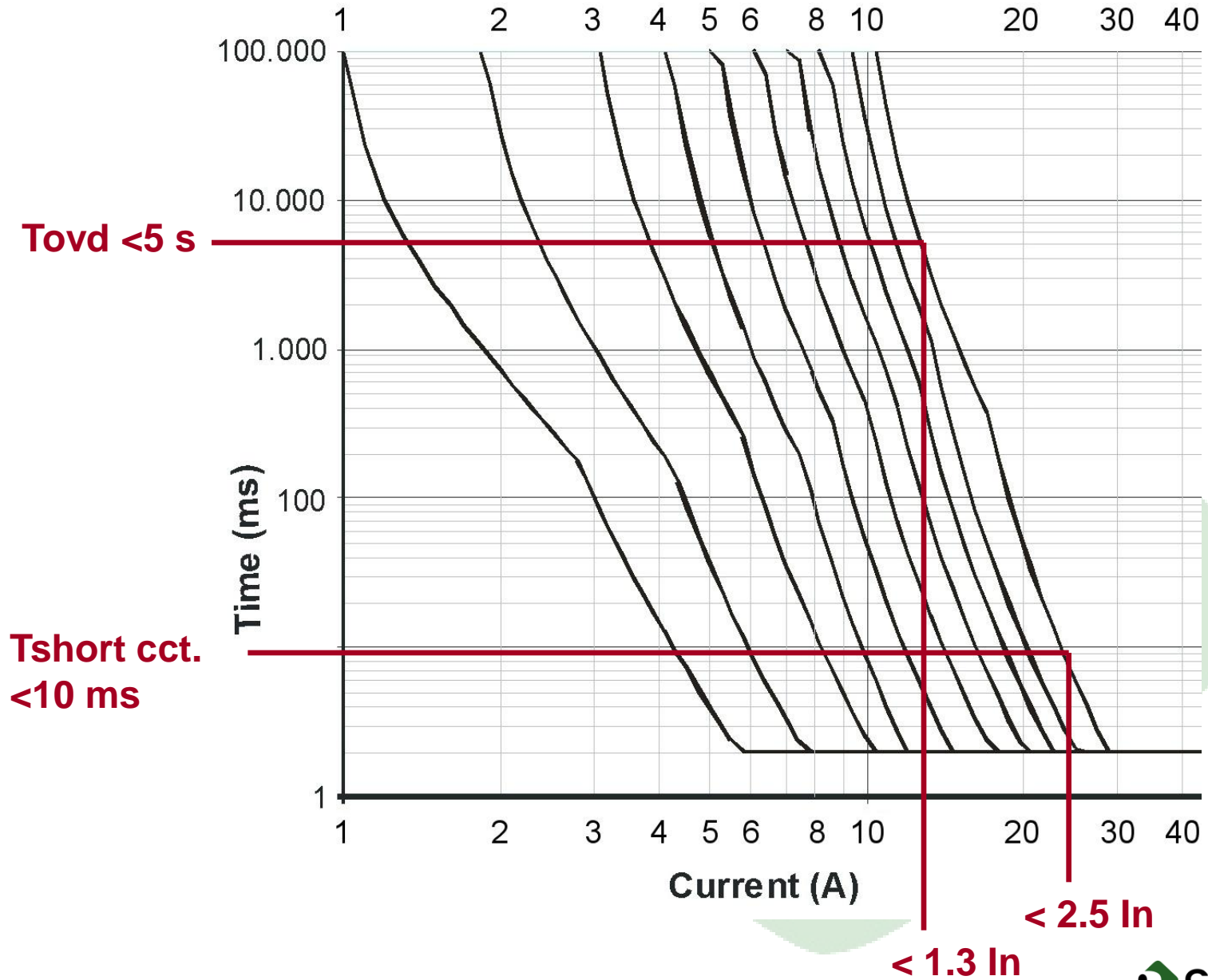
Cabur : New EN60204-1 and power supplies



Cabur Electronic Protection

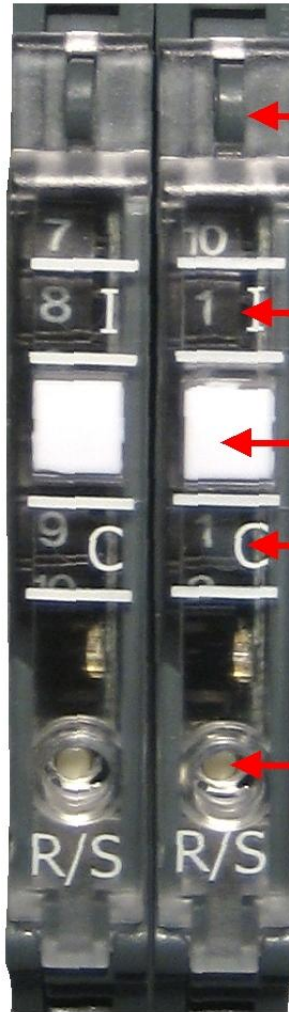
- programmable from 1 to 10A by 1A steps
- 3 programmable curves : fast, medium, delayed
- I switch-off short circuit < 3 of setted I < 10 ms
- I switch -off ovd < 1.5 of setted I < 5 s
- local ON / OFF load command with pushbutton
- remote ON / OFF safety command from PLC (100ms - OFF , 1s - ON)
- status led and remote signal
- slide on / off main contact
- 10 x 3mm copper bar for 24V potential distribution
- available with open BUS for remote events diagnosis
- UL508 approved

Cabur Electronic Protection fast curve



Cabur Electronic Protection

Cabur : New EN60204-1 and power supplies



- 1- sealable front cover
- 2- 1...10A rotary selector
- 3- marking tag
- 4- curve selector fast/ medium / delayed
- 5- ON/OFF local load command

Cabur Electronic Protection

- advantages compared with mcb :
- one item for 10 current values
- 3 sensitivity curves to suit load inrush peak
- safe ovd switch-off takes always less than 5s with a current lower than 1.5 of selected current
- accurate, fast, repeatable switch-off current treshold, indipendent form ambient temperature
- remote ON /OFF load command from PLC without opening the panel
- local and remote status signal
- only 8.1mm large

MTTF & MTBF & SIL

Power supplies and reliability

- life of any power supply can't be longer than their weakest component
- in any electronic devices the components with the shorter life are the electrolytic capacitors
- any 10°C increase in operating temperature of electrolytic capacitors reduces their life by 50%
- as now the safety functions of machinery can be controlled by electronic devices, the new EN60204 enforce not to have temperature higher than 45°C inside the control pannles

Power supplies and reliability

- **MTBF is an information on the medium statistic expectable life of a power supply**
- **MTBF can be calculated and indicated in many different ways, with very different results**
- **some MTBF are calculated according to a standard that allow to eclude the electrolytc capaictors from the calculation, a method that gives MTBF longher than 500.000 hours**
- **but the real MTBF of a good quality psu used at full load at 25°C ambient, ranges form 50.000 to 150.000h, equal to 5.7...17 years of continuous service ...**

- MTBF of 105°C industrial grade electrolytic capacitors 105°C used at rated U-I with different T measured on the component at 25°C ambiente
- 45°C on the capacitor 192.000 hours
- 55°C “ “ 96.000 hours
- 65°C “ “ 48.000 hours
- 75°C “ “ 24.000 hours
- 85°C “ “ 12.000 hours
- 95°C “ “ 6.000 hours
- 105°C “ “ 3.000 hours
- in good quality psu, with Tamb. 25°C and full load the capacitors work at 40...50°C and at 60...70°C when T ambient is 45°C

**Thank you
for your
attention**